Earned-Value Analysis on ISS

International Space Station (ISS) Implementation / Perspective

Project Management Challenge Conference 2005

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Impetus

- *Young Committee findings – program control deficiencies, including lack of across-the-board Earned-Value Management (EVM) implementation*
- *"Penalty Box" – halt at US Core Complete unless deficiencies corrected within two years*

Situation

- *Contractor EVM in place for major contracts (roughly half of program)*
- *Program nearly complete with transition to operations/sustaining phase*

Challenges

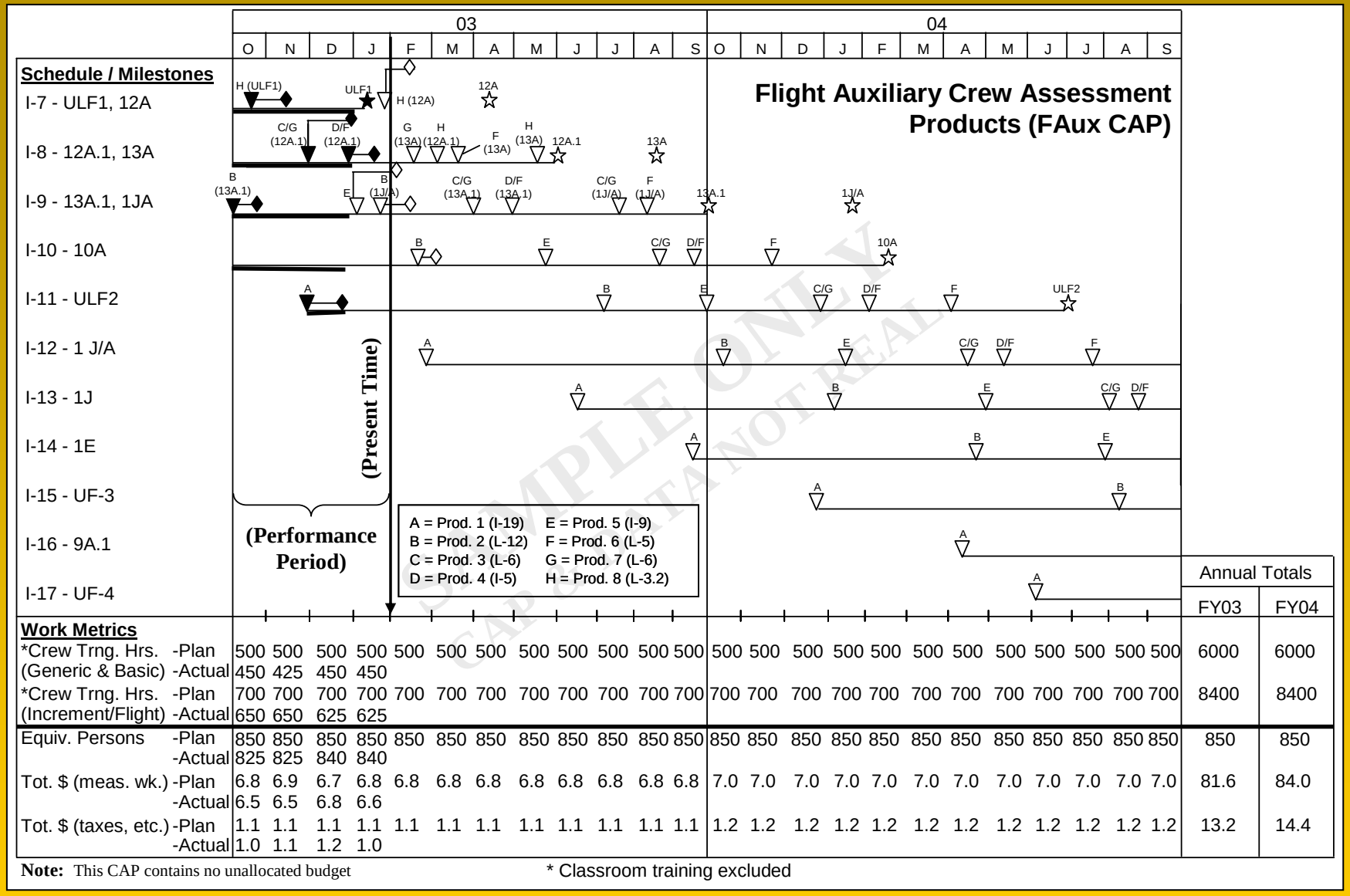
- *Implementation timetable – five months, including three months of dry runs*
- *Mid-program implementation – not to mention ops/sustaining implementation*
- *Limited resources*
- *Technical obstacles*
- *Make system useful – not just "check-marking a box"*

Background

Approach / Groundrules

- *Performance Measurement System (PMS) must be useful for mgmt. decisions*
- *Simpler is better – quicker implementation, faster turnaround, less overhead*
  - *Use data from certified (ANSI-748 compliant) contractor EVM systems as-is*
  - *Use available schedules, status presentation products, etc. where they exist*
  - *Adhere to EVM principles but don't assume overhead of fully-compliant system*
  - *Simplify data reports/displays/etc. for ease of communication with mgmt. team*
- *Create simplified EVM Control Account Packages (CAPs) for work content not yet covered by EVM reporting*
  - *Measure discretely only what makes sense to measure – don't force-fit 80% discrete*
  - *Focus on high-$, high visibility, &/or high-risk work content*
  - *Align CAP structure with major contracts & performing orgs.*
  - *Smaller performing orgs. collected into Cost-Performance-Only (CPO) CAP*
- *Develop overarching process to roll up pre-existing & new EVM data sources*
- *Shoulder as much of EVM system development work as possible – off-load orgs.*
- *Build "in-house" EVM toolkit to allow modification flexibility for assessments*
- *Peer review resultant system*

Background



Work Metrics																										Annual Totals	
		O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	FY03	FY04
*Crew Trng. Hrs. (Generic & Basic)	-Plan	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	6000	6000
	-Actual	450	425	450	450																						
*Crew Trng. Hrs. (Increment/Flight)	-Plan	700	700	700	700	700	700	700	700	700	700	700	700	700	700	700	700	700	700	700	700	700	700	700	700	8400	8400
	-Actual	650	650	625	625																						
Equiv. Persons	-Plan	850	850	850	850	850	850	850	850	850	850	850	850	850	850	850	850	850	850	850	850	850	850	850	850	850	850
	-Actual	825	825	840	840																						
Tot. $ (meas. wk.)	-Plan	6.8	6.9	6.7	6.8	6.8	6.8	6.8	6.8	6.8	6.8	6.8	6.8	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	81.6	84.0
	-Actual	6.5	6.5	6.8	6.6																						
Tot. $ (taxes, etc.)	-Plan	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	13.2	14.4
	-Actual	1.0	1.1	1.2	1.0																						

Note: This CAP contains no unallocated budget

* Classroom training excluded

Sample Data Input: CAP Resource-Loaded Schedule/Metrics

Proposed PMB changes for: 8

Current reporting month: Aug-03

*Note: Enter all resources on a per-month/-year (vs. cumulative) basis; express all costs in $M.

	Transferred Content		New/Deleted Content		Total Current FY Resource Phasing*												Total Out-year Resource Phasing*			
	From	To	+	-	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	FY+1	FY+2	FY+3	FY+4
BCD** #	CAP #	CAP #	(Y/N)	(Y/N)	BCD Resource Phasing, Current FY*												BCD Resource Phasing, Out-years*			
1																				
2																				
3																				
4																				
5																				
6																				
7																				
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25																				

Notes/Comments/Explanations/Rationales to Support Request for PMB Change

**General guidelines: Include only BCDs that add, delete, or transfer content to/from the CAP; exclude content-less funds transfers. Enter only one budget line item per line.

General instructions: Tab through fields to enter budget line-item changes & rationales; total $ are automatically summed at top; enter resources for content deletions as negative $.

Sample Data Input: CAP Monthly PMB Change Log

Proposed PMB changes for: **ISS** **Total Program** (without Research)

Current reporting month: Aug-03

Note: All costs in $M.

Current ISS Cumulative Performance Measurement Baseline (PMB)															
Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	FY+1	FY+2	FY+3	FY+4

		Log of Proposed Changes to ISS PMB, Phased by Month (Current FY) or Annually (Out-year FY)														
CAP #	CAP Title	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	FY+1	FY+2	FY+3	FY+4
1																	
2																	
3																	
4																	
5																	
6																	
7																	
8																	
9																	
10																	
11																	
12																	
13																	
R																	
Total Proposed Changes to ISS PMB:																	
Current ISS Cumulative PMB*:																	

*Note: "Current PMB" reflects only OG-concurred PMB-change proposals; Research not included in ISS PMB.

	Summary of PMB Change Justifications
1	
2	
3	
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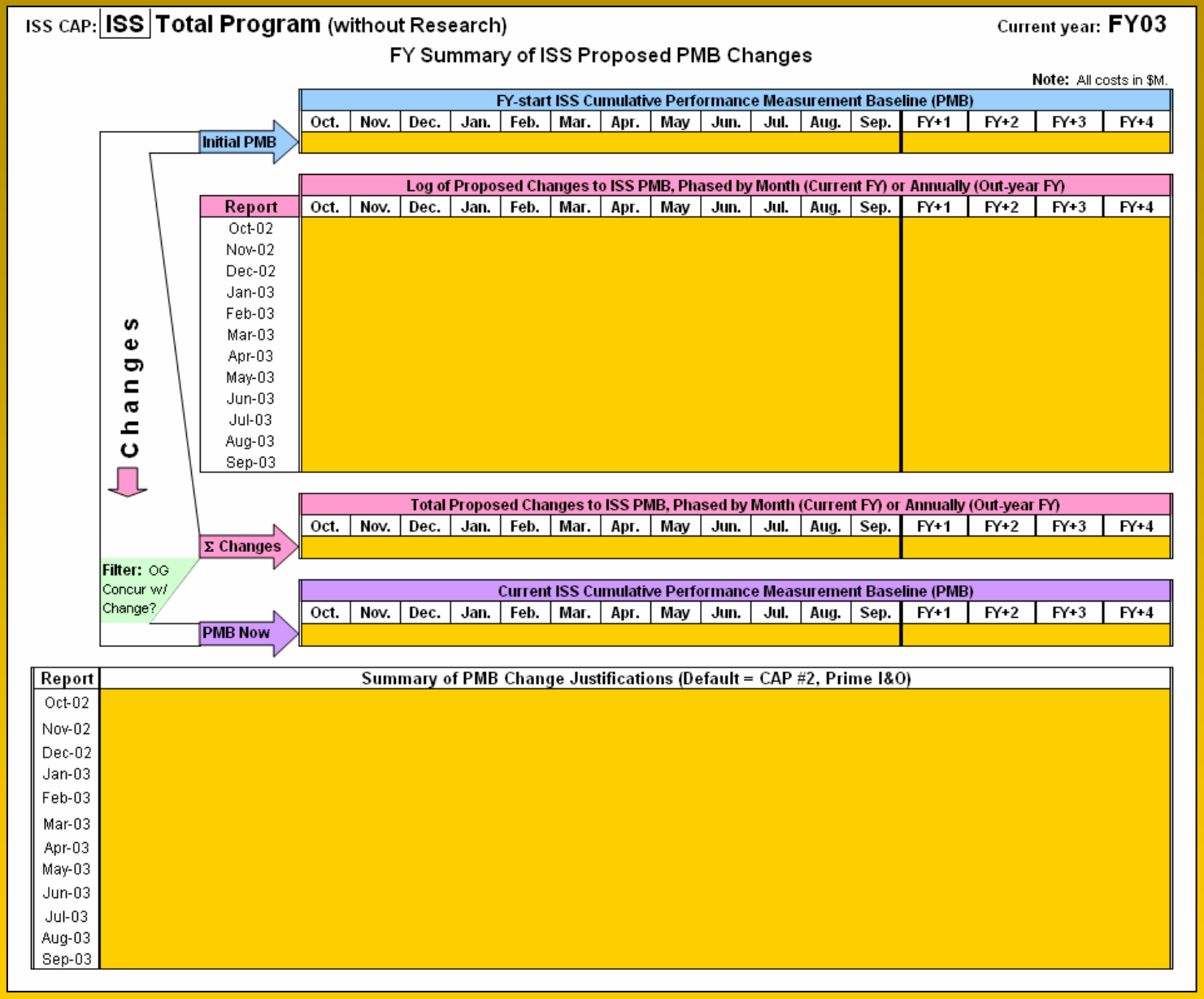
10	
11	
12	
13	
R	

Sample Data Output: Program Monthly PMB Change Log



Sample Data Output: Program FY PMB Change Log Summary

ISS PMS/EVM Monthly Summary (without Research)

	Prime	Non-Prime
SPI_{window}:		
CPI_{window}:		

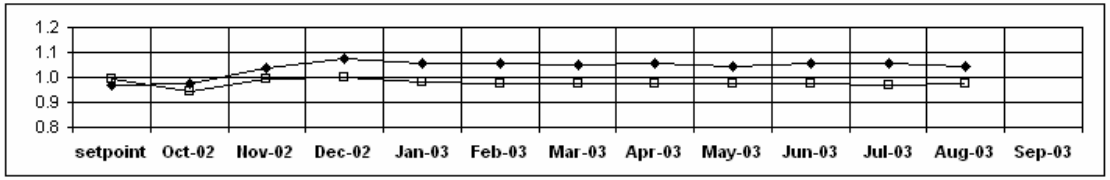
ISS Total	
Month:	Aug-03
SPI_{window}:	0.974
CPI_{window}:	1.046

Change from last month: ⇧ ⇩

Responsible Manager: OG/R. Fox **Prepared by:** OG/M. Jansen **Date:** 10/4/2003

Change Key: ⇩ = Degradation, below setpoint; ⇩ = Degradation, at/above setpoint; ⇧ = Improvement, below setpoint; ⇧ = Improvement, at/above setpoint; ⇔ = No change, below setpoint; ⇔ = No change, at/above setpoint

Cumulative SPI, CPI ***Legend:*** □ = SPI; ◆ = CPI



		ISS Total
PC_{window}:		Change from last month:
AC_{window}:		
EV_{window}:		⇧
BAC_{window}:		
EAC_{window}:		
VAC_{window}:		-1.5%

SV_{window}: -2.8% Change from last month: ⇧

Schedule variance explanation: (Required for SV_{window} > $1M & 5%.)

1
2
3
4
5
6
7
8
9
+
+

CV_{window}: 4.5% Change from last month: ⇩

Cost variance explanation: (Required for CV_{window} > $1M & 5%.)

1
2
3
4
5
6
7
8
9
+
+

Explanation for VAC_{window}: **PMS/EVM Window = FY03-07** (Required for VAC_{window} > 5%.)

1
2
3
4
5

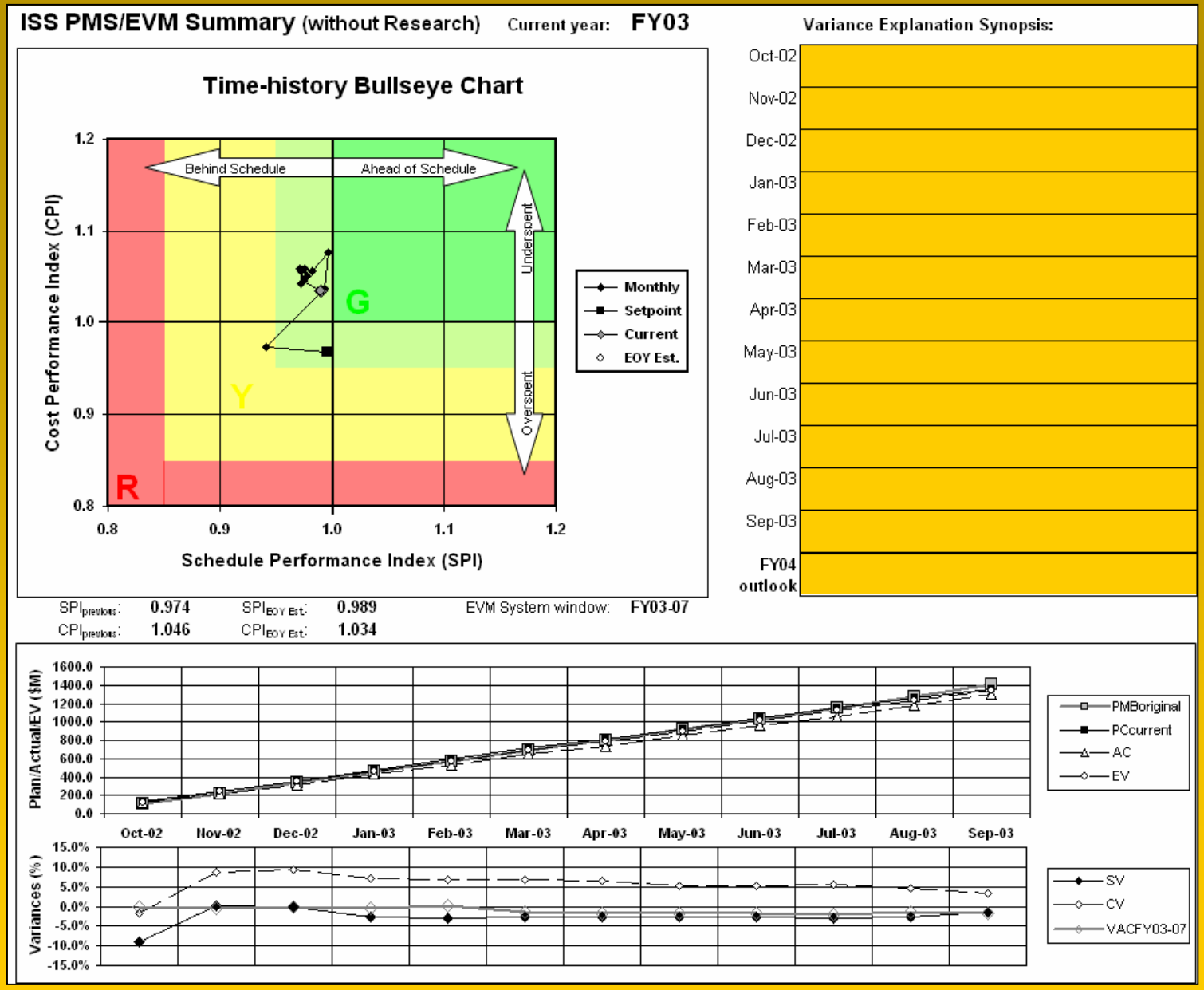
Corrective action(s) planned: (Required for all VAC_{window} requiring an explanation above.)

1
2
3
4
5

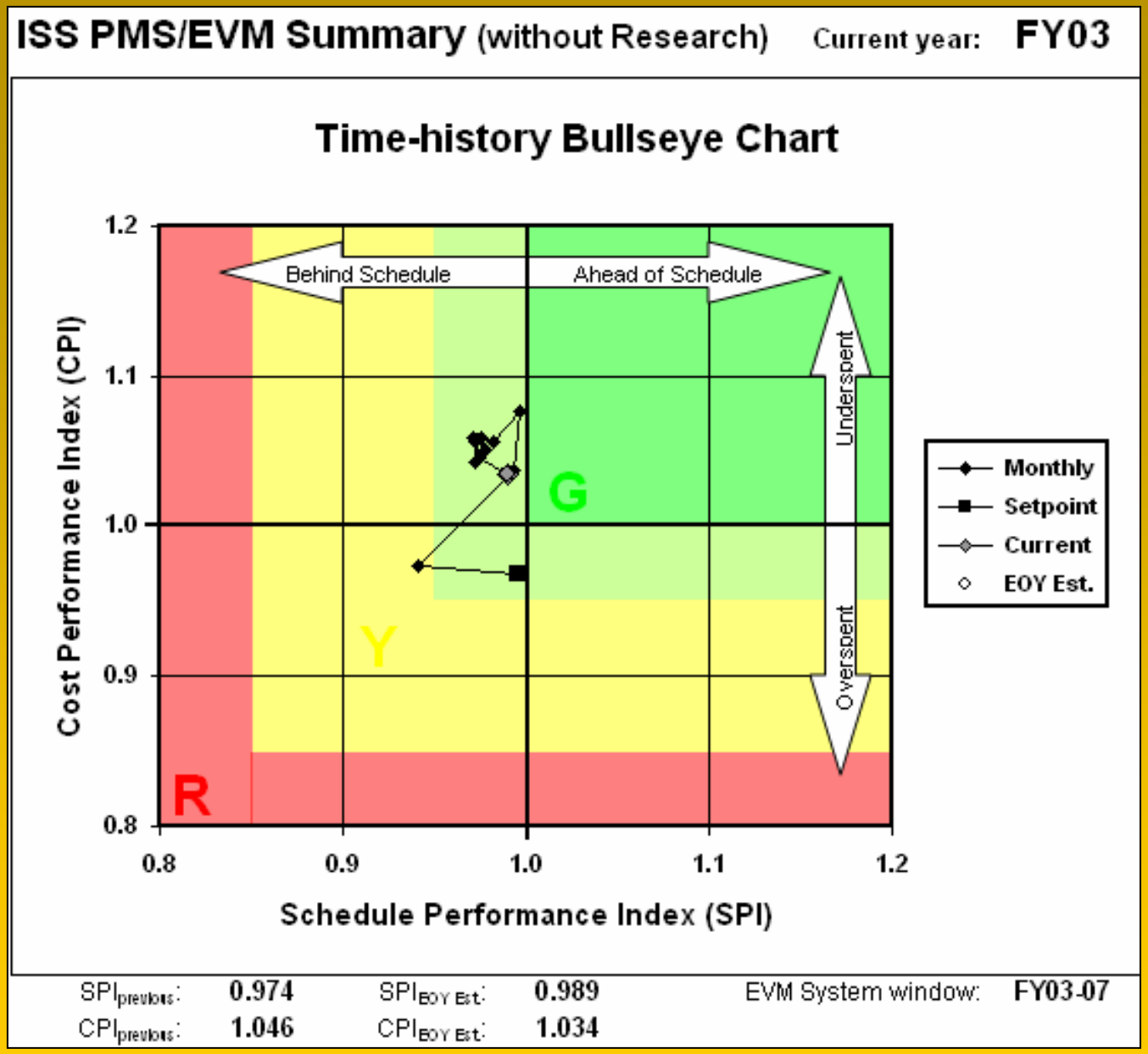
Notes: PMS initialization month: **10/02** Initial SPI: Initial CPI: SV setpoint: CV setpoint: **All $ in $M.**

Instructions: Tab to fill in header information only; all else calculated/plotted automatically. Explain variances > 5%.

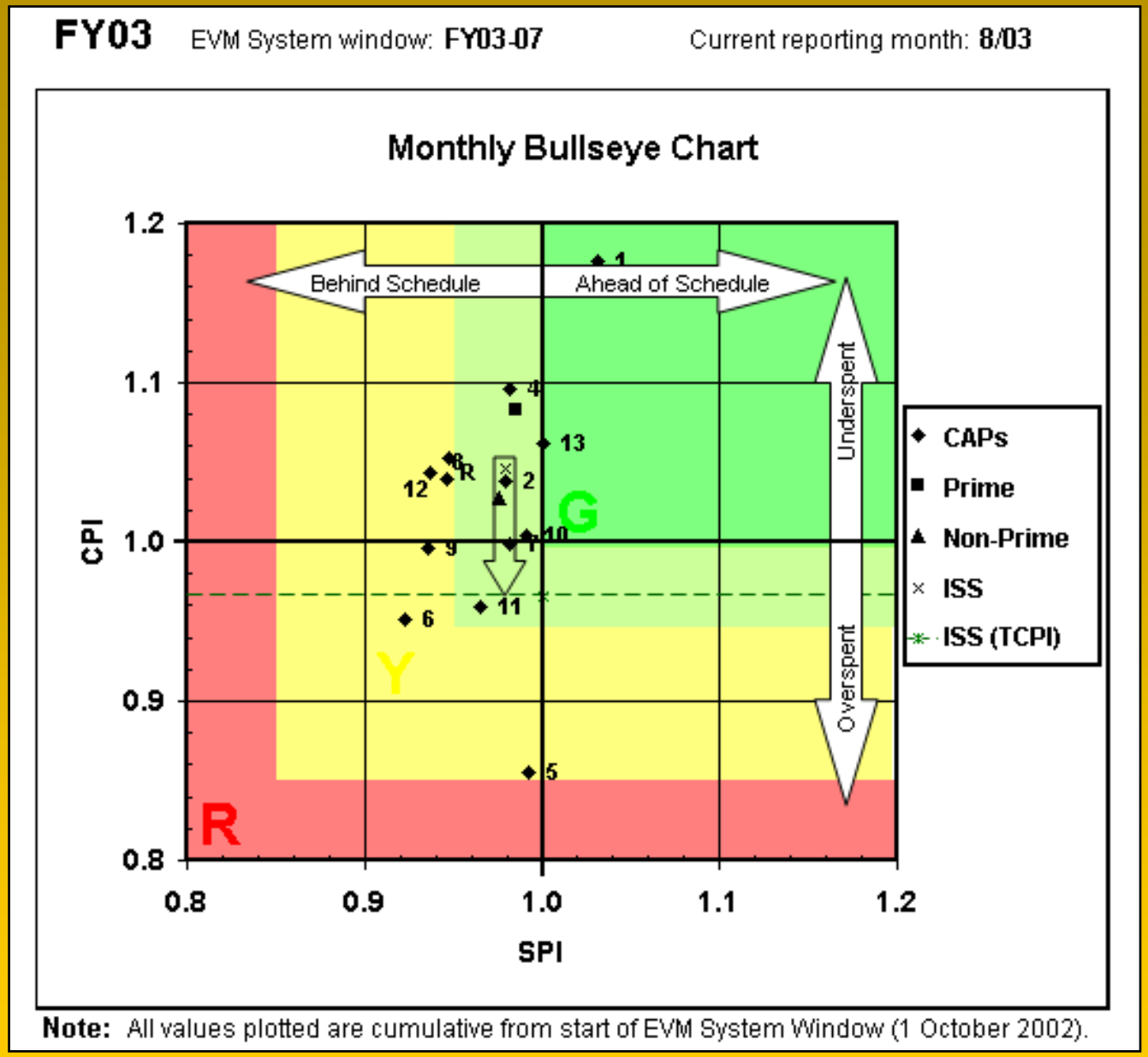
Sample Data Output: Program Traditional Summary Format



Sample Data Output: Program Simplified Summary Format



Data Display: Program Bullseye Time-History Plot



Data Display: Program Bullseye Scatter Plot

Quest for utility – what to do with all that EVM data?

- *Developed projections useful to Program mgmt. team*
  - *FY end-of-year (EOY) actual cost projection, factoring in non-EVM elements…*
    - *Management reserves, undistributed budget*
    - *Projected threats to reserves, based on quantitative risk analysis (QRA)*
  - *Breakdown of EOY projections of under-spend into roll-through & pure under-run*
    - *Encumbered under-spend (roll-through) tied to SPI < 1.0*
    - *Unencumbered under-spend (under-run) tied to CPI > 1.0 plus management reserves not projected to be required to cover QRA-predicted threats*
- *Used results of DoD EVM assessment of 300+ completed programs to develop…*
  - *Measure of believability of CAP Estimate at Completion (EAC) projections*
  - *Underperformance threat indicators*
- *Developed assessment scorecard & simple graphics to convey EVM data, projections, & assessment of data quality*
- *Incorporated EVM reporting into Program Early Warning System (EWS)*

EVM Data Assessment Approach

EOY projections

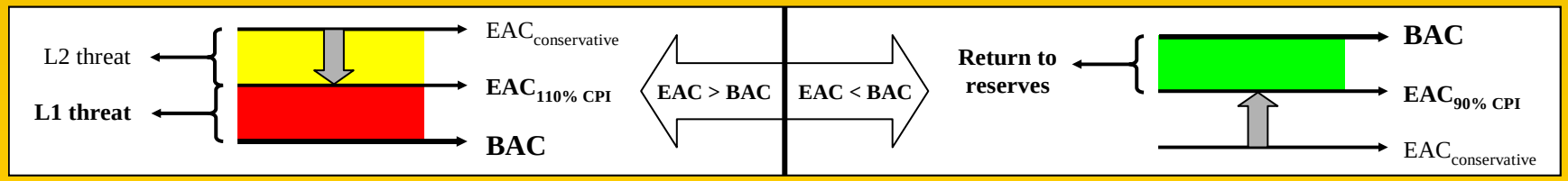
- *Unencumbered under-run (U/R) = unused reserves + positive performance*
  = [(Budget – PMB) – $QRA_{threats}$] + PMB(CPI – 1)
- *Encumbered roll-through (R/T) = value of unaccomplished work*
  = PMB(1 – SPI)
- *Under-spend (U/S) = U/R + R/T; therefore, EOY = Budget – U/S*

EAC reasonableness check

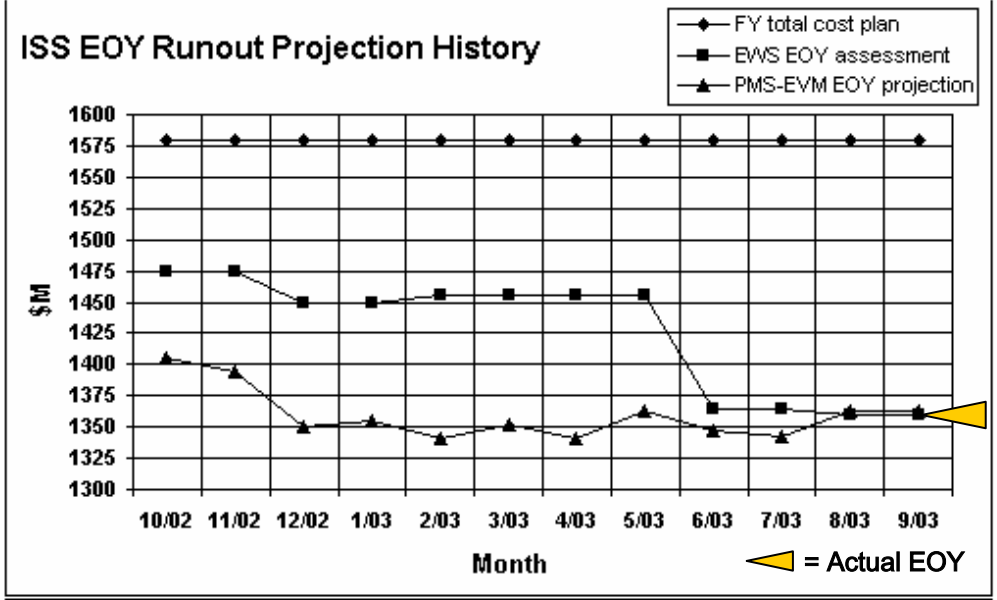
- *If TCPI </> CPI by more than 10%, EAC is unreasonably over-/understated*
- *If TCPI > CPI, raises assessment flag even if within 10% of CPI*

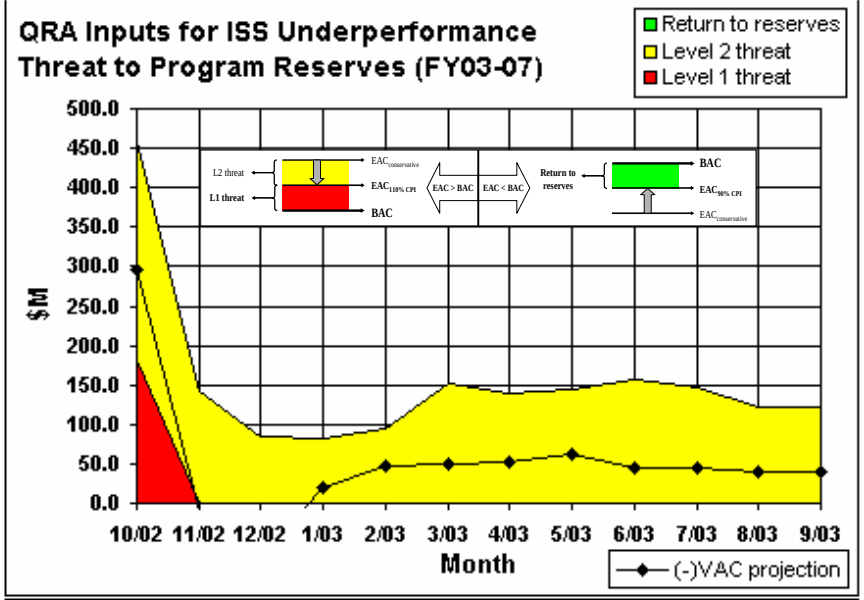
Underperformance threat

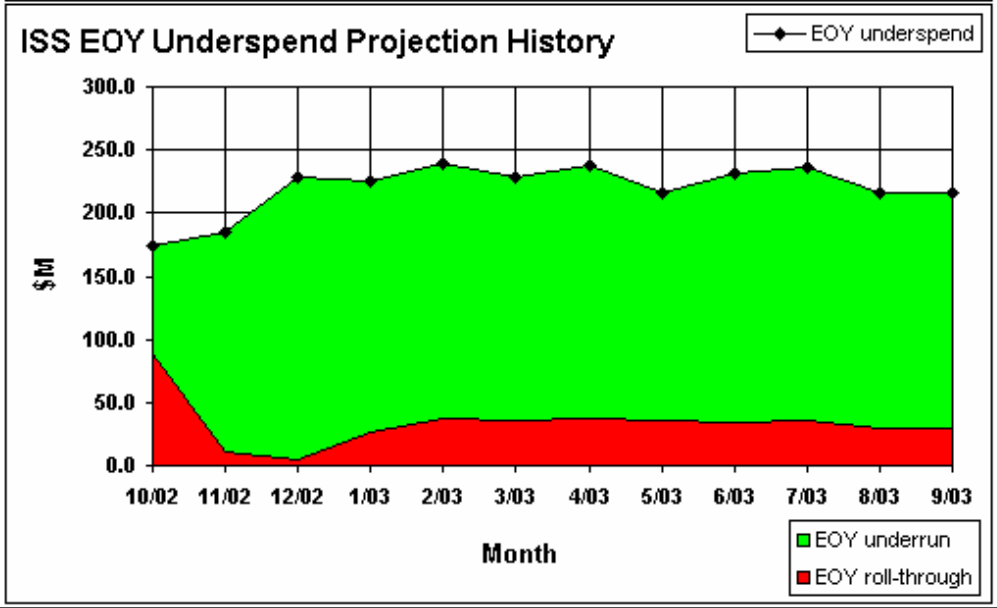
- *Translates above EAC reasonableness conditions into threats against reserves*

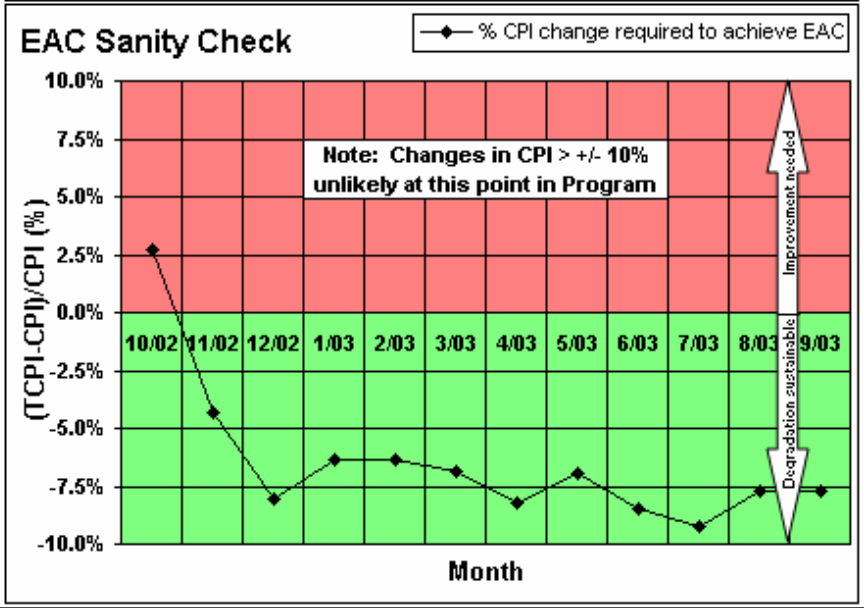


Assessment Innovations









Data Assessment: Program Health & FY Projections

CAP #	CAP	CAM	Current SPI	Current CPI	Reported Status	Current TCPI	ΔCPI$_{reqd.}$ (%)	Projected EOY R/T ($M)	Projected EOY U/R ($M)	Projected -VAC ($M)	Assessed Status
1			1.032	1.177	G	0.923	-21.6%	0.0	19.8	-13.7	G
2			0.979	1.038	G	0.988	-4.7%	8.3	14.3	12.7	G
3			0.972	1.354	G	0.769	-43.2%	2.5	22.2	-6.9	Y
4			0.982	1.096	G	0.976	-11.0%	1.4	6.5	-1.7	G
5			0.993	0.855	Y	0.749	-12.4%	0.2	-4.8	2.1	Y
6			0.923	0.952	Y	0.880	-7.5%	3.6	-2.2	15.1	Y
7			0.981	0.999	G	0.892	-10.6%	1.7	-0.1	7.3	G
8			0.946	1.039	Y	0.987	-5.0%	3.0	2.0	6.6	G
9			0.936	0.996	Y	1.001	0.5%	7.6	-0.4	22.5	Y
10			0.991	1.004	G	0.999	-0.5%	0.8	0.3	2.4	G
11			0.965	0.959	G	1.031	7.5%	1.7	-2.0	5.2	Y
12			0.937	1.044	Y	0.894	-14.3%	4.0	2.5	8.3	G
13			1.000	1.062	G	1.001	-5.8%	0.0	11.1	-14.5	G
R			0.947	1.052	Y	0.979	-7.0%	6.5	5.8	20.2	N/A
ISS*			**0.979**	**1.046**	G	**0.966**	**-7.7%**	**30.1**	**61.8**	**41.0**	G

***Note:** Denotes Program roll-up without Research

Key: G G = SPI & CPI > 0.95; darker green indicates SPI & CPI > 1.00

Y = SPI &/or CPI between 0.85 & 0.95; neither index < 0.85

R = SPI &/or CPI < 0.85

Assessment comments:

CAP 1:
CAP 2:
CAP 3:
CAP 4:
CAP 5:
CAP 6:
CAP 7:
CAP 8:
CAP 9:
CAP 10:
CAP 11:
CAP 12:
CAP 13:
ISS*:

ISS-level EOY projections:

Total underspend ($M):	215.5	R/T (content) to next FY ($M):	30.1	U/R ($M to (+)/from (-) reserves):	185.4	$\Delta_{PMS-EVMS}$:
Current FY cost plan ($M):	1579.0	EWS EOY assessment ($M):	1360.0	PMS-EVM EOY projection ($M):	1363.5	0.3%

Program Status & Data Assessment: Assessment Scorecard

Performance Factors (PF)

- *Common traditional PF = 0.8CPI + 0.2SPI*
  - *Based on implementation of EVM in development (DDT&E) phase – tend to solve issues with $ to hold schedule*
  - *Excellent method for projecting performance of remaining DDT&E work, but…*
- *Majority of ISS Program is in ops/sustaining phase*
  - *Tend to slide schedule to stay within limited budget*
  - *Alternative PF developed for ops/sustaining work: PF = 0.8SPI + 0.2CPI*
  - *Lends itself well to LCC estimates, bow-wave assessments, etc.*

Percent Discrete

- *Traditional rule-of-thumb – 80% of PMB or better under discrete EV measures – also based on implementation of EVM in development phase*
  - *High-risk work easily planned beforehand in measurable blocks*
  - *Still a good guideline for measuring remaining DDT&E-related work blocks, but…*

Additional Assessment Innovations / Findings

Percent Discrete (contd.)

- *Finding for ops phase: Expect lower coverage under discrete measures*
  - *Low-risk, often on-demand work with few or no pre-planned, measurable milestones*
  - *Doesn't make sense to force-fit essentially Level-of-Effort (LoE, aka Cost Performance Only or CPO) work into discrete measures & incur the associated overhead*
- *For ISS, percent discretely measured content closer to 40%*
  - *Only that high because of remaining development work in Program*
  - *Percent decreases annually as development tasks complete; purely ops CAPs tend to flip-flop the 80/20 rule completely*
- *LoE, the bane of classical EVM, must be viewed differently once past DDT&E; in ops phase, LoE is simply the nature of a majority of the daily work*
  - *Tends to be low-risk, routine work which is highly unlikely to cause schedule variance (therefore making "planned v. actual" an appropriate measurement method)*
  - *If majority of Program is ops, then having overall performance heavily influenced by LoE segments of work is appropriate & accurate*
  - *High percent of legitimately LoE work helps enable low-overhead EVM implementation*

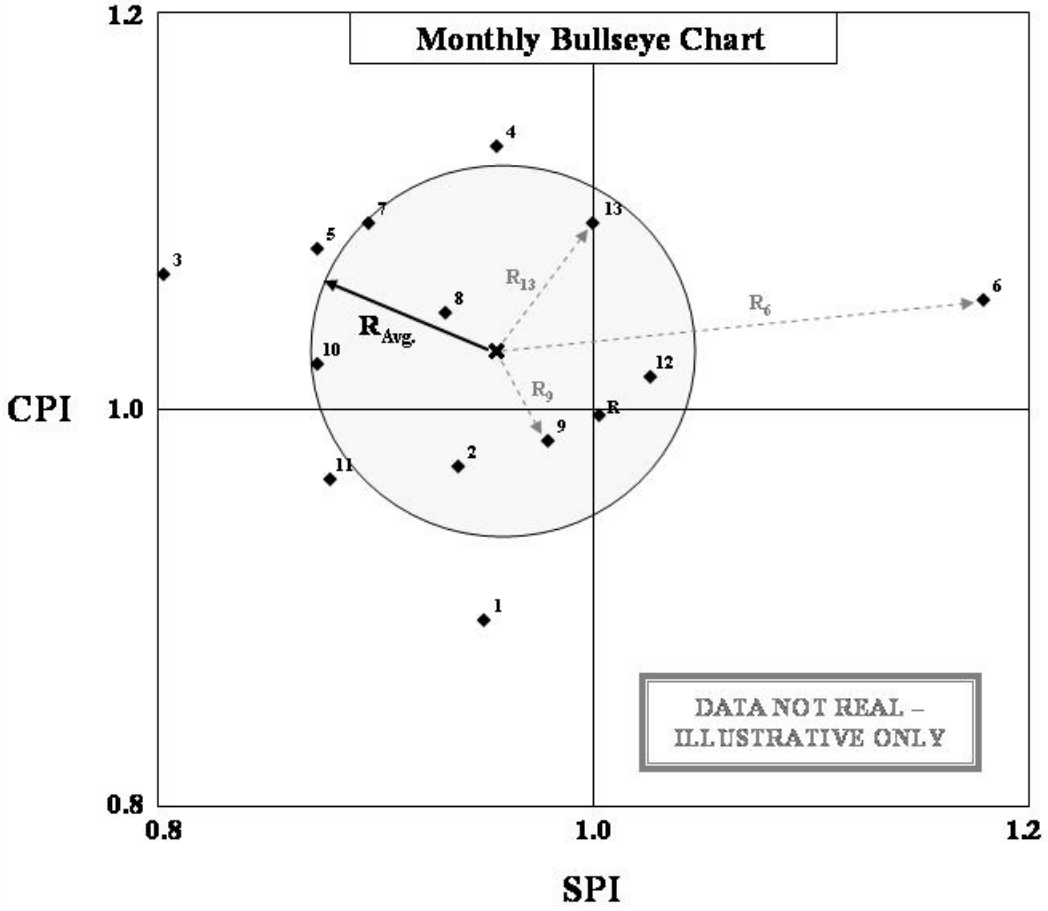
Additional Assessment Innovations / Findings

Key question – when can EVM data be factored into decisions?

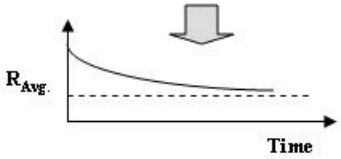
- *Put another way, when is an apparent trend the result of something real?*
  - *Startup instabilities similar to any mathematical system model*
  - *Expect data to converge slowly to value representative of true performance*
  - *Deviations/trends noted after system convergence can be considered real*
  - *Variance explanations should concentrate on "real" trends*
- *Two measures of quality assessed*
  - *CAP scatter about ISS aggregate on Bullseye Scatter Plot*
    - *CAP characteristic performance an outgrowth of work type, mgmt. style, etc.*
    - *Expect CAP scatter about aggregate to converge to non-zero steady-state*
  - *For each CAP & ISS aggregate, scatter about centroid on Bullseye Time-History Plot*
    - *Any given month can vary widely; CAP (& ISS) have characteristic performance*
    - *Expect month-to-month scatter about centroid to converge to zero steady-state*
- *All assessments based on cumulative EVM data*
- *All of the above purely mathematical – still performed input spot sanity-checks!*

Quality Metrics

ISS PMS/EVM System Convergence Metric #1
(CAP Scatter About ISS Aggregate)

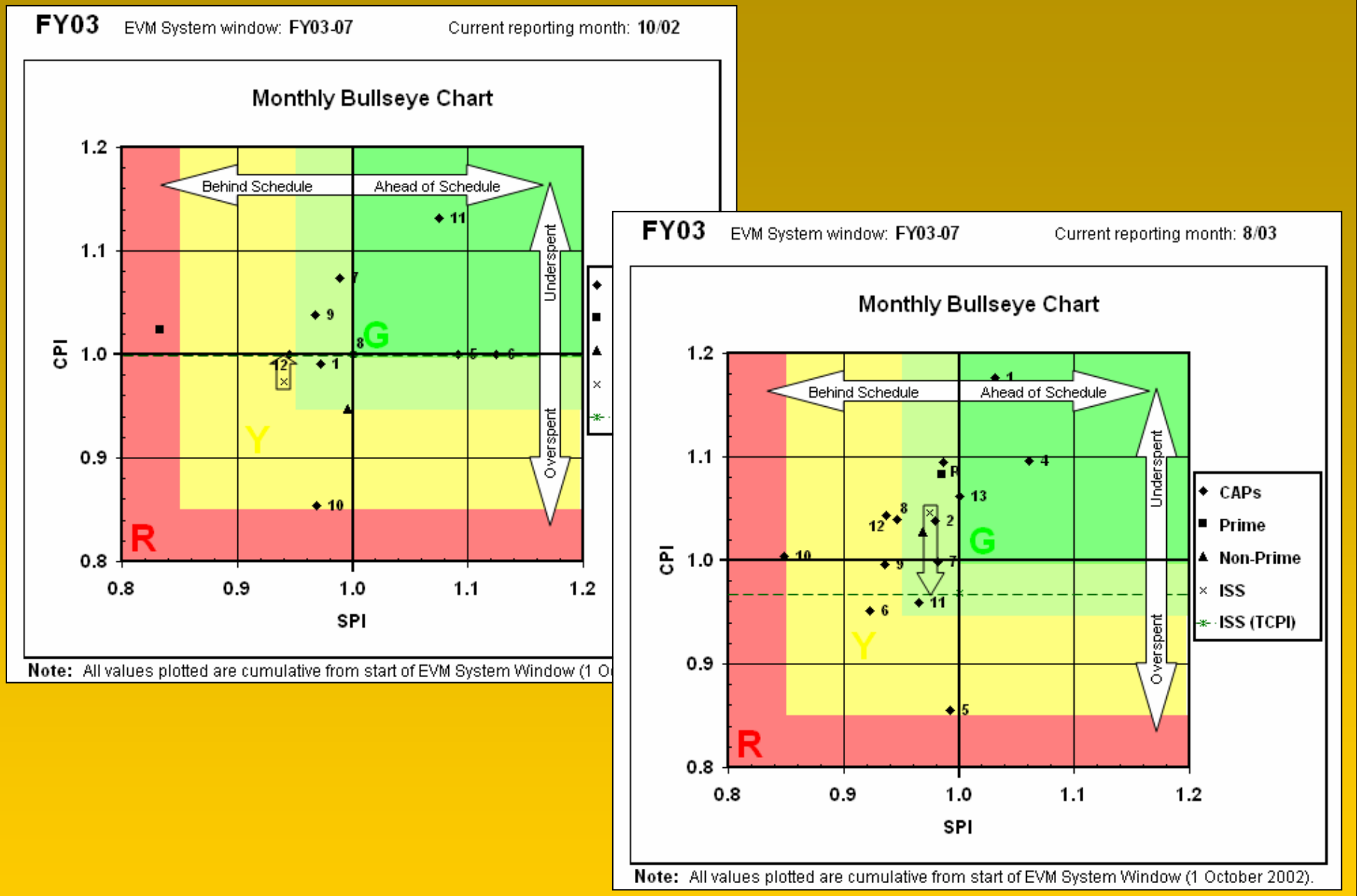


- $R_{Avg.}$ indicates the average radial distance from the ISS CPI/SPI aggregate point (✖) to any given CAP's CPI/SPI datum (♦)
- As ISS PMS/EVM system matures, the expected behavior is for $R_{Avg.}$ to decrease & asymptotically approach some finite (i.e., non-zero) value

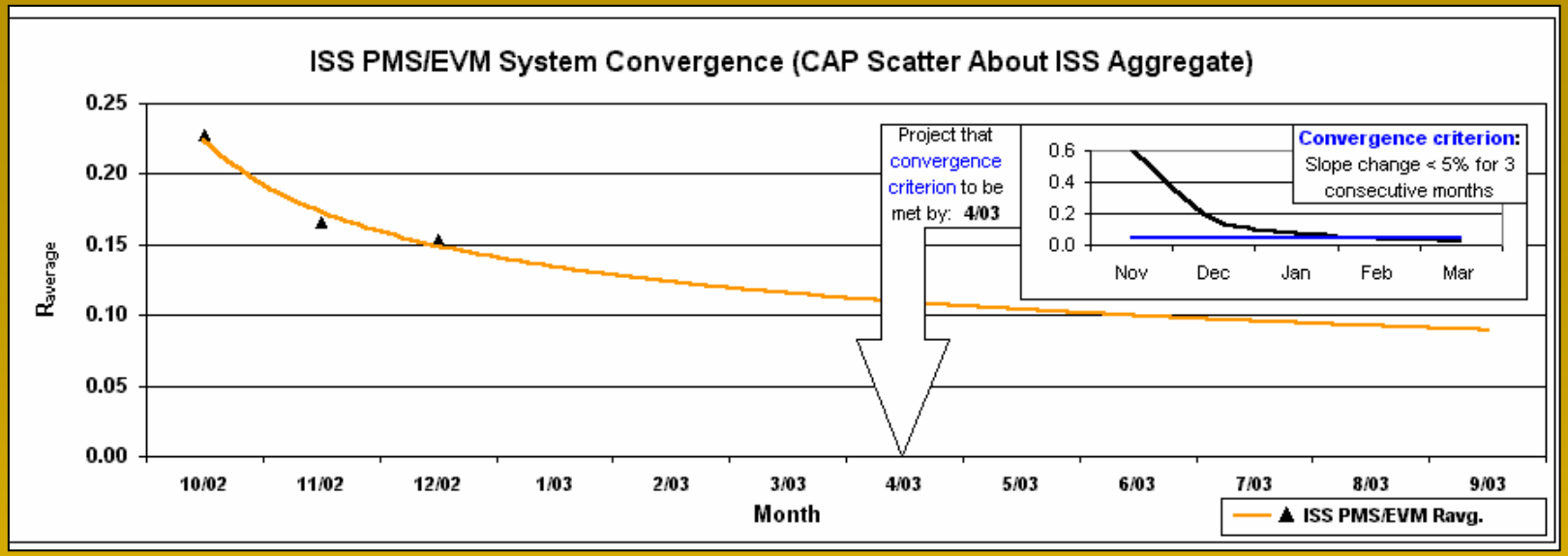


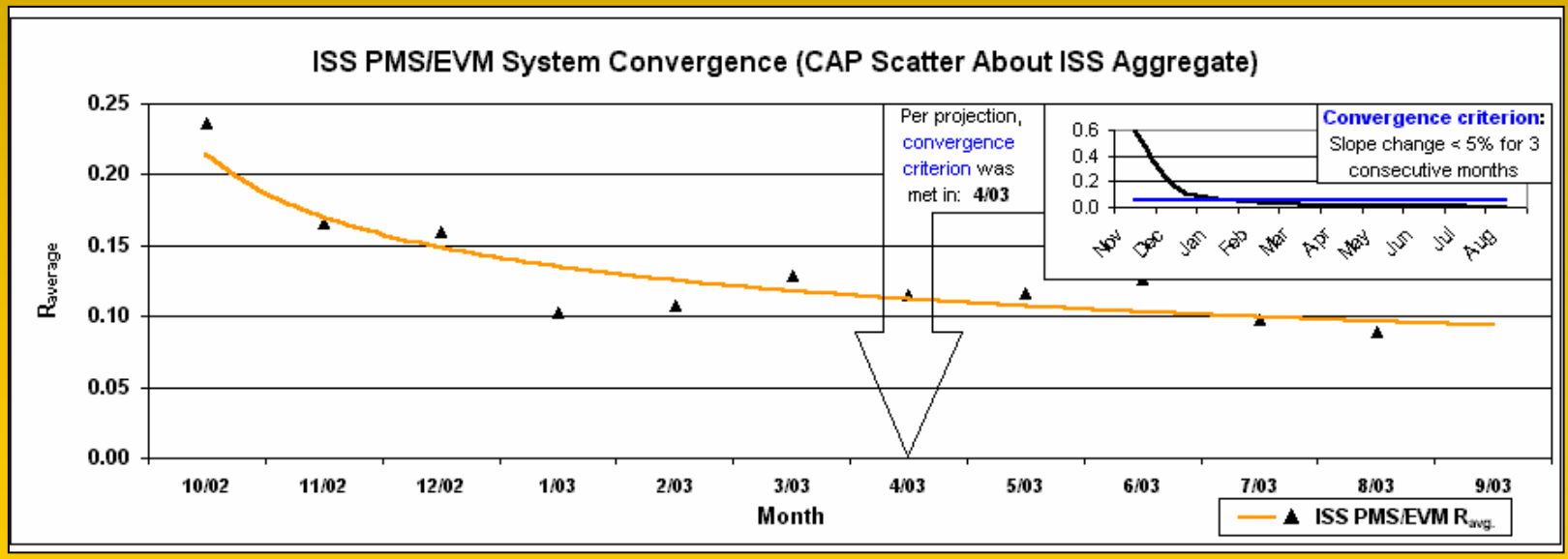
- $R_{Avg.}$ will always > zero since CAPs will always perform at different efficiencies/levels/etc. relative to each other
- Maturity criterion: $R_{Avg.}$ monthly rate of change is < 5% for 3 consecutive months

Quality Metric 1: CAP Scatter Convergence



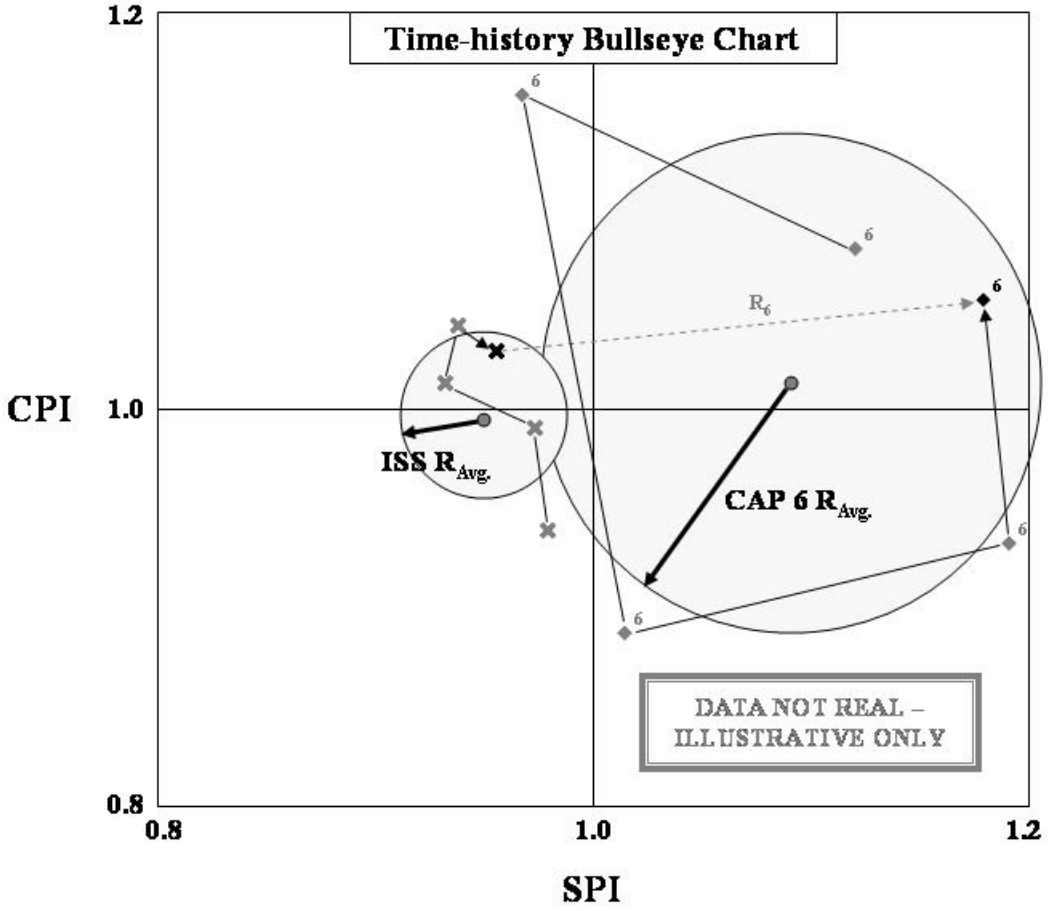
Quality Metric 1: Illustration



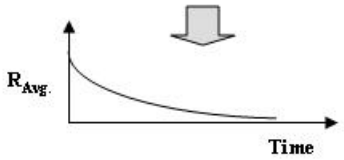


Quality Metric 1: Illustration

ISS PMS/EVM System Convergence Metric #2
(Time-history Scatter Convergence)

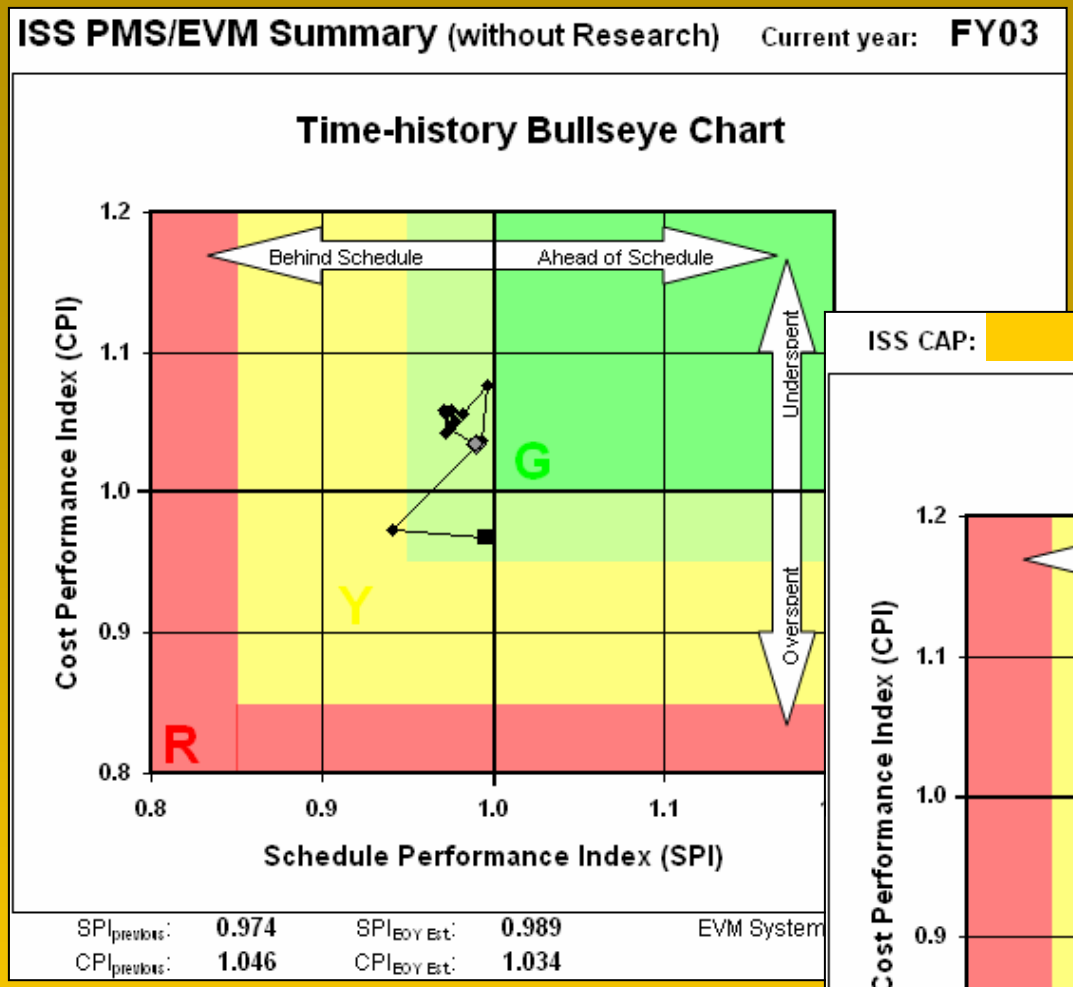


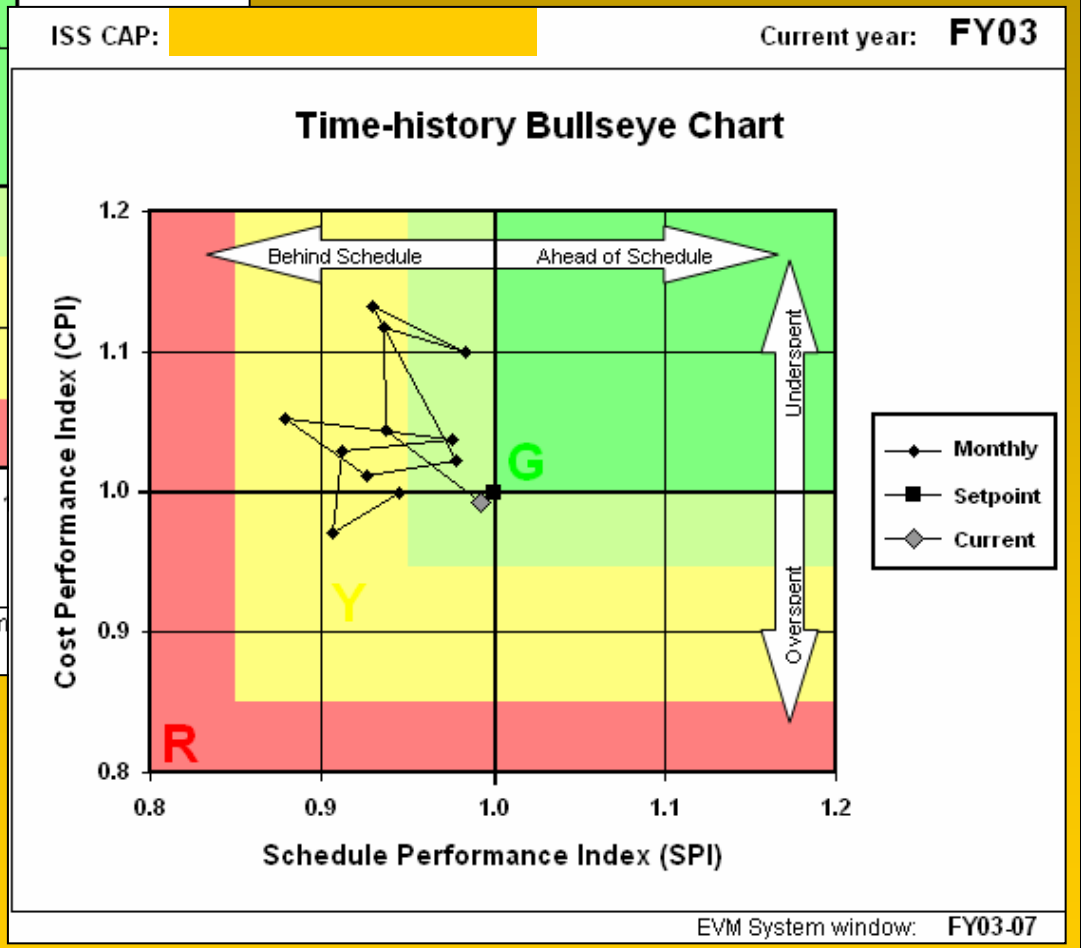
- As time progresses, the ISS CPI/SPI aggregate point (✖) migrates, eventually settling down to its "true" value; the same holds for any CAP (◆)
- $R_{Avg.}$ (whether for CAPs or ISS aggregate) here measures average radial distance from centroid of CAP or ISS CPI/SPI time-history data (●) to any given CPI/SPI datum
- As ISS PMS/EVM system matures, the expected behavior is for $R_{Avg.}$ to decrease & asymptotically approach zero



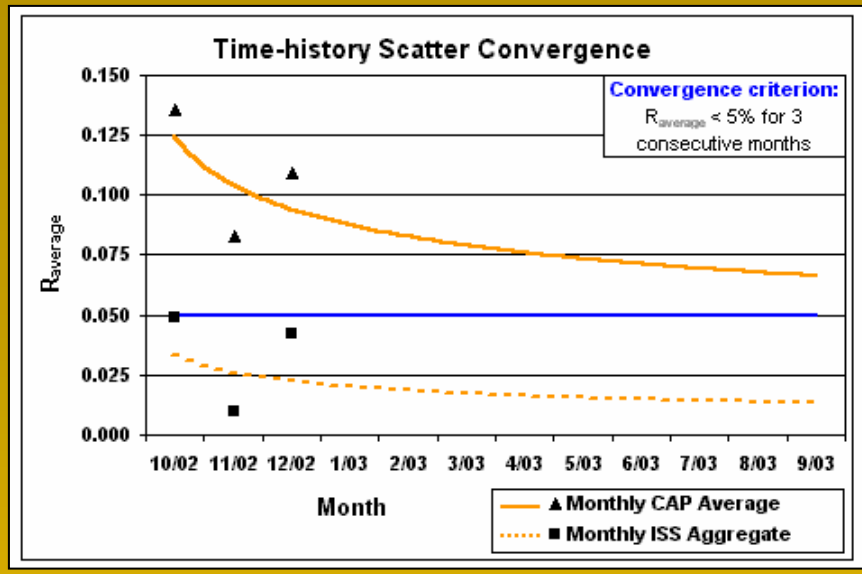
- Maturity criterion: $R_{Avg.}$ is < 5% for 3 consecutive months

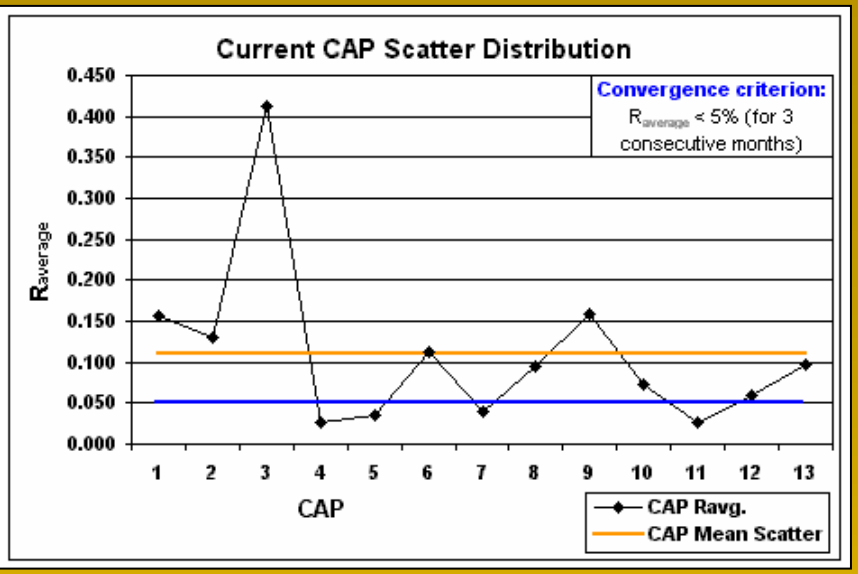
Quality Metric 2: Program, CAP Time-History Convergence

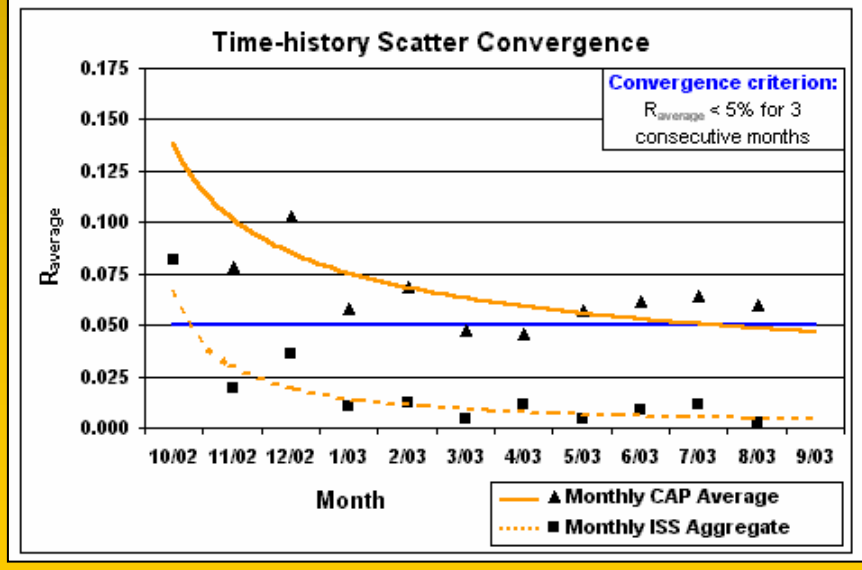


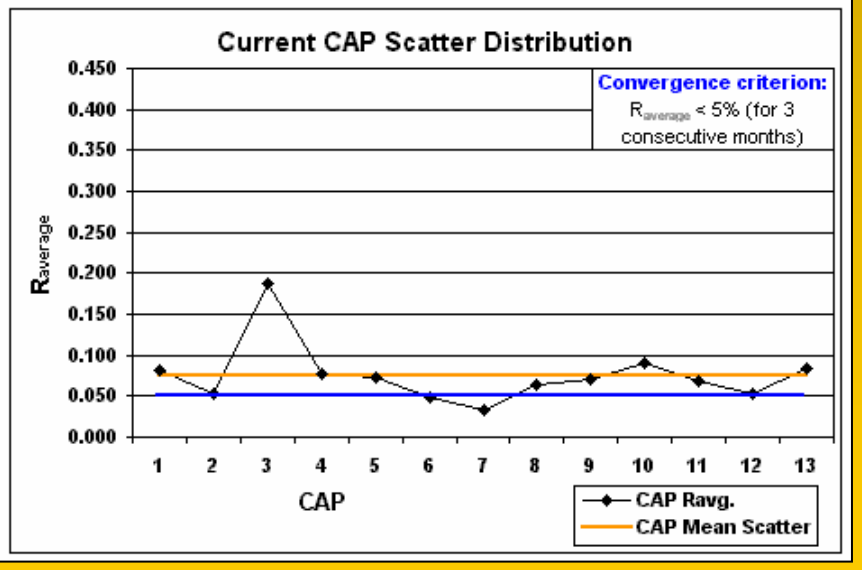


Quality Metric 2: Illustration

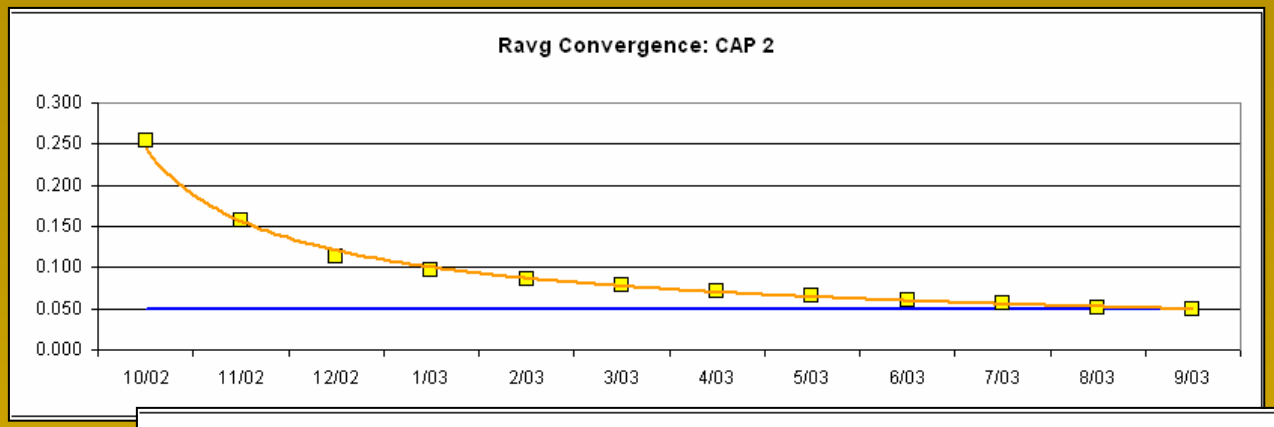


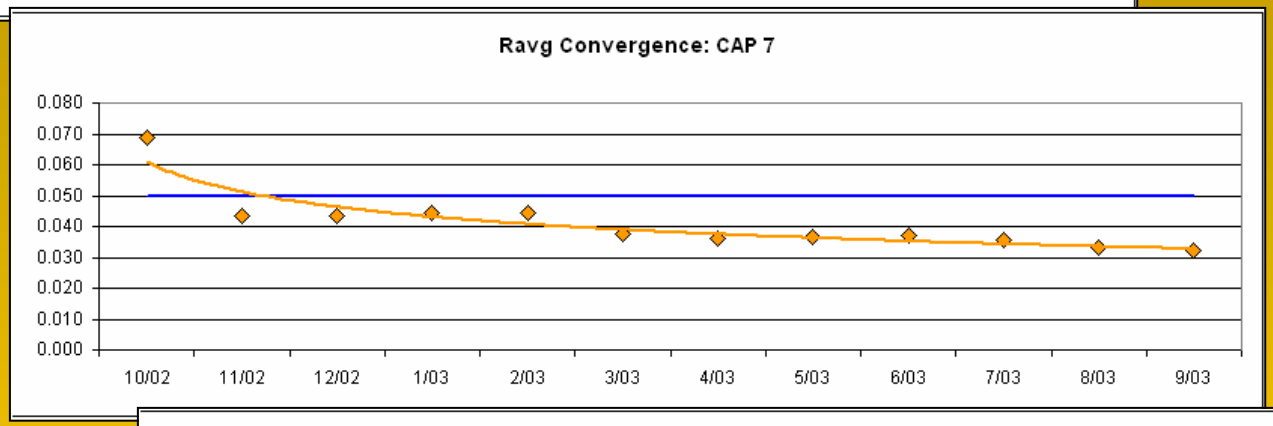


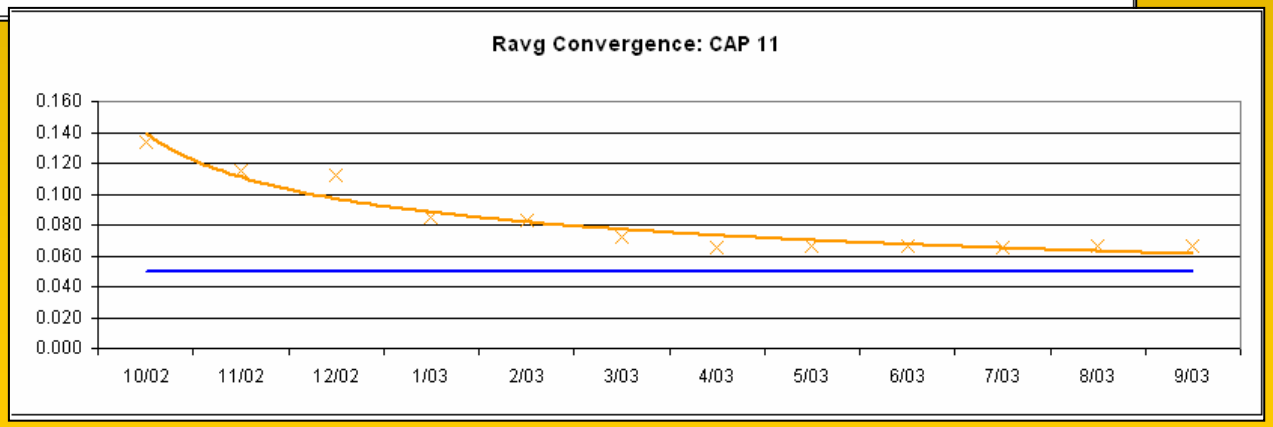




Quality Metric 2: Illustration



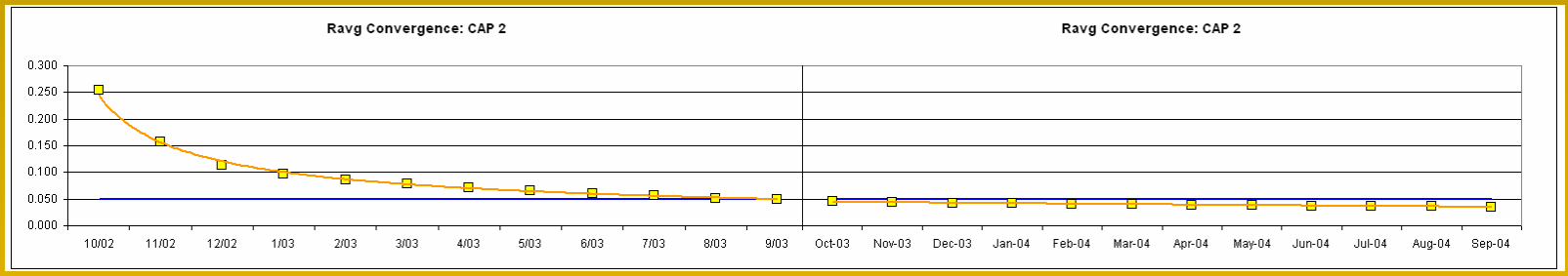


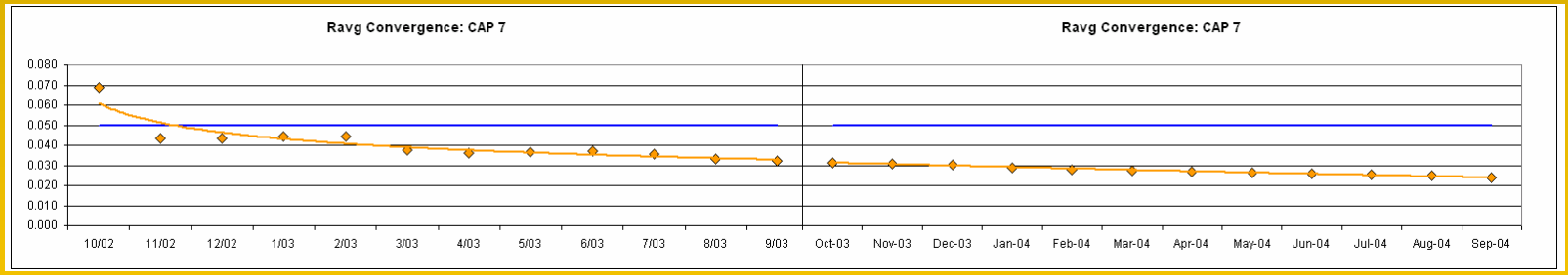


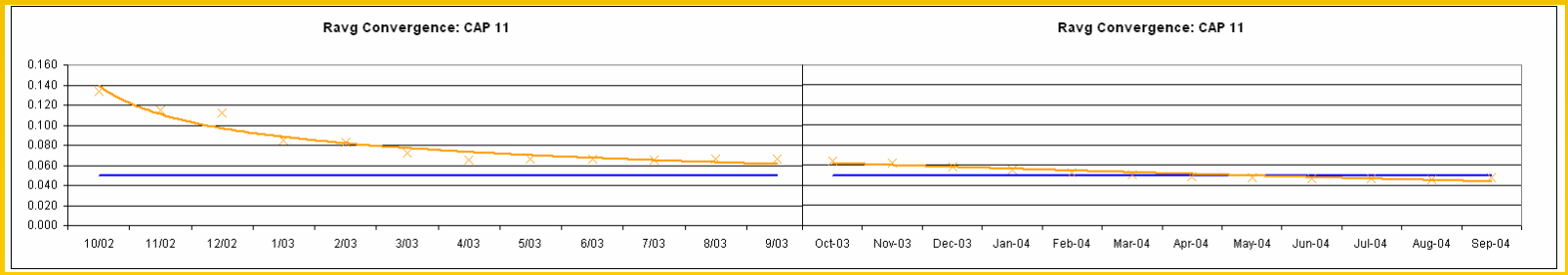
Quality Metric 2: Illustration

CAP metrics indicate may now legitimately take assessments down a level (i.e., CAP level EVM has matured)

- *General status*
- *EOY & other projections*







Quality Metrics: Post-Script

Current usage

- *Management Information System – Key Program Performance Indicator*
- *Early Warning System – Assessment & Projections*
- *ISS Monthly Program Review – Status to Program Manager*
- *Special assessments*
- *Contractor award fee evaluation (Program-wide)*

Evolving usage

- *Contractor award fee evaluation (JSC-wide)*
- *Underperformance threat – potential reserves impact assessment*

Enhancements in work / under consideration

- *Toolbox upgrade*
- *Multi-use resource-loaded schedules – automatic link*
- *Link to cost/schedule QRA tool*

Summary

Implementation

- *Meaningful EVM is possible with greatly reduced overhead*
- *Less is more – measure discretely only what's important to the bottom line, use what's available (don't reinvent the wheel), etc.*
- *The more you do for the managers who need to buy in, the easier the buy-in*
- *Don't be afraid to innovate to tailor the implementation to your needs*
- *Simple quality metrics can help determine when EVM data trends are due to real events, v. an artifice of system startup*

Usage

- *Even "crude" CAP data, when combined to form a program aggregate, can support program-level management decision making almost immediately*
- *The potential uses for EVM data extend well beyond mere EAC projection*
- *EVM, while a primary program control tool, should be used in conjunction with other methods of program assessment – especially at the CAP level*

Lessons-learned

Young Committee "Penalty Box"

- *Committee reconvened to assess interim progress – presented findings to NASA senior management on 12/11/02, 13 months after initial critical report*
  - *EVM implementation cited explicitly as one of the major program control improvements which made the Committee comfortable with ISS's direction*
  - *Recommended ISS be allowed to proceed with full 6-person crew capability*
- *ISS formally "released from penalty box" during following POP, when Capability Upgrades (i.e., the on-hold hardware) was added to the budget baseline*

NASA & the eGov't element of President's Management Agenda

- *ISS's PMS was cited by HQ/CIO when asked for an example of use of EVM in management at NASA during a review by OMB in 9/04*
  - *Review supported OMB's determination of NASA's stoplight status for the eGov't element of the President's Management Agenda*
  - *Review conducted by OMB's Administrator for eGov't, who was impressed that HQ used readily available charts – taken as evidence that NASA manages by them*
- *NASA went "green" on this critical element, largely due to achieving the EVM objective of the scorecard*

Epilogue